ABSORPTIVE MICROWAVE SINGLE POLE SINGLE THROW SWITCH

FIELD OF THE INVENTION

[0001] This present invention relates to microwave switches, and in particular, to absorptive microwave switches.

BACKGROUND OF THE INVENTION

[0002] Absorptive switches are attractive components for a system designer, as the input, and ideally output, reflection coefficient of the switch remains constant regardless of the state of the switch. This reduces the effects of the switch on system parameters such as frequency pulling of a signal source, or the inducement of other transient effects that can be problematic in very short interval time-based systems.

[0003] One drawback of absorptive switches is that a dummy, or additional load, has to be included in the circuitry to be presented to the input network to absorb any incident energy when the switch is selected to be in a non-transmit or isolated state. This dummy load takes up valuable circuit board space in an integrated circuit (IC) design that directly translates to increased circuit cost and reduced yield.

[0004] Thus, there is presently a need for an absorptive switch which does not utilize a dummy load.

SUMMARY OF THE INVENTION

[0005] An embodiment of the present invention comprises a switch circuit including a first differential amplifier pair providing a portion of an isolation channel, a second differential amplifier pair providing a portion of a transmit channel, and a third differential amplifier pair providing a control bias for selecting either the transmit channel or the isolation channel.

[0006] An embodiment of the present invention also comprises a method for providing isolation between the input and output of a circuit comprising the steps of providing a first channel including at least one first differential amplifier pair, said first channel providing isolation between the input and output of the circuit, providing a second channel including at least one second differential amplifier pair, said second channel

providing coupling between the input and output of the circuit, and providing a control bias which selects one of the first channel or the second channel.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] Figure 1 shows switch circuit according to an exemplary embodiment of the present invention.

[0008] Figure 2 shows the switch circuit of Figure 1 implemented as an integrated circuit.

[0009] Figure 3(a) is a graph showing a frequency versus decibel (dB) response of the input reflection coefficient for the switch circuit of Figure 1 in both the isolated and transmission states.

[0010] Figure 3(b) is a graph showing shows a frequency versus decibel (dB) response of the transmission characteristics for the switch circuit of Figure 1 when the switch circuit is in alternately the isolated and the "transmit" states.

DETAILED DESCRIPTION

[0011] An embodiment of the present invention comprises an absorptive microwave switch circuit that provides 35 decibels (dB) of isolation between input and output over 15 Gigahertz (GHz)-26GHz range, yet is only 500 micrometers (μm) by 250μm in size. Since 24GHz has been used recently to provide pulsed radar systems for short-range automotive sensors, the present invention will be particularly applicable to such systems. The switch circuit ensures that there is almost no perceptible change in the input reflection coefficient between the transmission or absorptive states. In the transmit state the switch provides gain for the input signal between 14.2GHz and 25.5GHz, and has a ldB loss bandwidth of over 12GHz. Lastly, the use of a constant current biasing scheme allows extremely fast switching between states allowing the switch to be used to generate pulses of 200 picoseconds (pS) in length with rise and fall times of approximately 60pS. The entire switch, including biasing circuitry, requires only 12 milliamp (mA) from a +5 volt (V) supply.

[0012] As discussed above, the present invention will be particularly applicable to automotive sensing systems, which are required to detect objects at distances between 5 centimeters (cm) and 10 meters (m) to 30m, often with a distance resolution of less than

10cm. These requirements translate directly to a minimum inter-pulse period of less than 2 nanoseconds (nS) (correspond to the two-way flight time of a pulse reflected from an object 10cm from the sensor), and a required pulse width of less than 500pS. These design considerations require a circuit which has fast switching.

[0013] Figure 1 shows an absorptive single pole single throw (SPST) switch circuit 100 according to an exemplary embodiment of the present invention which includes an input terminal V_{in}, and output terminal V_{out}, and a control terminal $V_{control}$. The switch circuit 100 also includes a first differential amplifier pair 110 including transistors Q1 and Q2, a second differential amplifier pair 120 including transistors Q3 and Q4, and a third differential amplifier pair 130 including transistors Q5 and Q6. The collectors of each of transistors Q1-Q4 are all coupled to a supply voltage V_{cc}. Transistors Q3 and Q4 further include inductors 140, 150 coupled between the collectors and V_{cc}. The collector of transistor Q5 is coupled to the emitters of transistors Q1 and Q2, and the collector of transistor Q6 is coupled to the emitters of transistors Q3 and Q4. The emitters of transistors Q5 and Q6 are coupled to a current source I_{ee}.

[0014] In operation, transistor Q6 is biased on by control signal $V_{control}$ to select the "transmit" state of the switch 100. This is accomplished by providing a control signal $V_{control}$ which is above the junction voltage of transistor Q6 on the negative side (e.g., -0.7 volts). In the "transmit" state, signals entering input terminal V_{in} are coupled to output terminal V_{out}. The biasing on of transistor Q6 in turn biases on transistors Q3 and Q4, thus creating a signal path from the input terminal V_{in} to the output terminal V_{out} at the respective collectors of transistors Q3 and Q4. Thus, the input signal is transmitted to the output.

[0015] Alternatively, if $V_{control}$ selects the "isolation" state of the switch 100 by biasing transistor Q5 on, signals entering input terminal V_{in} are decoupled from output terminal V_{out}. As with the "transmit" state, this is accomplished by providing a control signal $V_{control}$ which is above the junction voltage of transistor Q5 on the positive side (e.g., +0.7 volts). The biasing on of transistor Q5 in turn biases on transistors Q1 and Q2, and thus creates a signal path from the input terminal V_{in} to the midpoint between the bases of transistors Q2 and Q3. Accordingly, the input is "isolated" from the output.

[0016] In the "transmit" state, the high input impedance of the transistor pair Q1, Q2 when turned off minimizes the circuit loading on Q3 and Q4, and the circuit appears as a standard differential amplifier, that when matched, can provide gain to an input signal. Bias chokes in the form of inductors 140, 150 used to isolate the DC voltage supply V_{cc} from the output microwave signal V_{out}.

[0017] In the "isolation" state, the high impedance presented by Q3 and Q4 is such that they load input circuit only lightly. The input voltage V_{in} is transferred primarily to the Q1, Q2 pair where it sees a virtual RF ground. The differential pair Q1, Q2 can thus be considered as an ideal unilateral amplifier.

[0018] The switch circuit 100 provides for several advantages. First, the control signal $V_{control}$ applied differentially across transistors Q5 and Q6 allows for easy selection of either the transmission or isolated state. Additionally, the constant current steering between the two differential amplifier pairs 110, 120 ensures extremely high speed switching between the two states, as the switch never has to be depleted of high current densities. In particular, the switch circuit provides a pulse width of approximately 220pS, with rise and fall times around 60pS at 24 GHz.

[0019] The switch circuit 100 may be implemented using any commercially available transistor based semiconductor process, such as a Silicon Germanium (SiGe) process (e.g., Atmel SiGE2basic).

[0020] Figure 2 shows a photograph of the switch circuit 100 of Figure 1 implemented in SiGe. As should be understood by those of ordinary skill in the art, the switch circuit 100 may be implemented in other substrates as well, such as Silicon Gallium Arsenide (SiGaAs) or Indium Phosphide (InP). As shown in Figure 2 the switch circuit also includes input and output matching networks (not shown in the idealized circuit diagram of Figure 1) comprising a series of inductors and resistors designed for operation at a center frequency of 24GHz. The first and second differential amplifier pairs 110, 120 are disposed adjacent to each other and connected in parallel across an input signal network. The collectors of Q3-Q4 are connected to an output-matching network, while the collectors of Q1-Q2 are connected directly together and further connected directly to source voltage V_{cc}. The

total circuit area of the switch circuit shown in Figure 2 including input and output matching networks and bias circuits is 500μm by 250 μm.

[0021] Figure 3(a) shows the input reflection coefficient of the switch circuit 100 in both its transmission and absorption (isolation) states. The difference between the reflection coefficients in each state is extremely small, as the DC current flowing through the network has remained constant. This validates using the virtual radiofrequency (RF) ground of the differential pair Q1-Q2 as a load rather than the more conventional technique of steering the input signal into a matched load to provide the absorptive condition. In the transmit state, shown in Figure 3(b), an ON-OFF ratio of over 30dB is achieved over 14GHz-28GHz, and a 1dB insertion-loss bandwidth of over 12GHz is measured.

[0022] Although the invention has been described in terms of exemplary embodiments, it is not limited thereto. Rather, the appended claims should be construed broadly to include other variants and embodiments of the invention which may be made by those skilled in the art without departing from the scope and range of equivalents of the invention.